

10-20-00

10/19/00

JC957 U.S. PTO

Attorney's Docket No. 0001-004

A

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application
Commissioner of Patents and Trademarks
Washington, D.C. 20231

JC714 U.S. PTO
09/692075
10/19/00

New Application Transmittal

herewith for filing is the patent application of
Ken Harris

Type of Application

This new application is for a Original (nonprovisional) filing

PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING
SURFACE

**Papers Enclosed Which Are Required For Filing Date under 37 CFR 1.53 (b) (Regular) or
37 CFR 1.153 (Design) Application**

20 Pages of specification

5 Pages of claims

1 Pages of Abstract

1 Sheet of drawing

20 Pages of Appendices

Declaration of Oath

Attached hereto

Inventorship Statement

The inventorship for all the claims in this application is the same.

Language

English

Priority

None

Filed

Fee Calculation

CLAIMS AS FILED			
Number Filed	Number Extra	Rate	Basic Fee 37 CFR 1.16 (a) \$355.00
Total Claims (37 CFR 1.16 (c))	27-20 =7	x \$18.00	\$126.00
Independent Claims (37 CFR 1.16 (b))	3 -3 = 0	x \$76.00	-0-
Multiple dependent claims if any (37 CFR 1.16(d))		+\$240.00	

Filing Fee Calculation \$ 481.00**Small Entity Statement**

Attached hereto

Fee Payment Being Made at This Time

Enclosed for Basic Filing Fee

\$481.00**Method of Payment of Fees**Check in the amount of \$481.00**Instructions as to Overpayment**

Refund to undersigned

I HEREBY CERTIFY THAT THIS CORRESPONDENCE IS
BEING DEPOSITED WITH THE UNITED STATES POSTAL
SERVICE AS EXPRESS MAIL IN AN ENVELOPE ADDRESSED
TO: COMMISSIONER OF PATENTS AND TRADEMARKS,
WASHINGTON, D.C. 20231, ON 10/19/00

LABEL NO. Robert G. Lev
NAME EK 93170578US
SIGNATURE [Signature]

[Signature]
Robert G. Lev
Reg. No. 30, 280
4766 Michigan Boulevard
Youngstown, Ohio 44505
(330) 759-1424

Date : October 19, 2000

Applicant or Patentee : Ken Harris Attorney=s Docket No.: 0001-004

Serial or Patent No. : _____

For : PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING SURFACE**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 CFR 1.9 (F) AND 1.27 (C)) - SMALL ENTITY CONCERN**

I hereby declare that I am

- ☒ Independent Inventor
☐ the owner of the small business concern identified below;
☐ an official of the small business concern empowered to act on behalf of the concern identified below;

I hereby declare that the above identified small business concern qualified as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9 (d), for purposes of paying reproduced fees under section 41 (a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties control or has the control to power both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled **PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING SURFACE** by inventor(s) Ken Harris described in

- ☒ the specification attached hereto.
☐ application Serial No., filed,
☐ patent no., issued,

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to this invention listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9 (c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9 (d) or a nonprofit organization having rights to the invention averring to their status as small entities. (37CFR 1.27)

NAME OF ORGANIZATION : _____

ADDRESS : _____

☒ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change of status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))

I hereby declare that all statements made herein are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Ken Harris

SIGNATURE 

PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING SURFACE

Technical Field

The present invention relates generally to the field of embossing photo-profiled data. In particular, the present invention is directed to a material and a method for using the subject material to eliminate steps between photo-profiling and embossing.

Background Art

Embossing tools are used in a wide variety of applications for transferring data from one medium to another. One example is the mass production of holograms, using embossing tools, for the holographic portions of credit cards. Holograms are also created for a large number of other products, including periodical advertising, wrapping paper and other decorations, a wide range security devices, packaging, and artwork. Mass production of such holograms is carried out by impressing a film with an embossing die containing the holographic relief pattern.

The embossing die or tool is the key feature of this process, and requires a high degree of precision in its manufacturing in order to successfully generate

large quantities of high quality holograms. Conventionally, such tools are produced using a number of steps. The first step involves a photoresisted plate exposed to a holographic interference pattern used to form the “master” hologram. After exposure to the holographic light pattern, the photoresist is developed to form a surface-relief pattern in the photoresist corresponding to the holographic interference pattern.

Then a thin layer of nickel is electroformed onto the relief surface of the photoresist to transfer the interference pattern. The nickel layer is then peeled away from the photoresist. This nickel layer becomes the master, and a second nickel layer is made as a copy of the first. The second nickel layer serves as the stamper, and is clamped to a substrate, either by being wrapped around the cylinder or being held to a flat plate which forms a die. Each of the layers is known as a shim. Generally there are two shims used, with one being kept aside as a master while the other is used as a stamper. The metal die is then used to stamp or press the transparent film, impressing the holographic interference pattern onto the film, thereby creating the production holograms. This process is used for a wide variety of different types of holograms, including those constituted by translucent films viewed with laser light, defraction patterns, “2D 3D” holograms, and virtually any other holographic pattern that lends itself to mass

production.

Unfortunately, there are certain limitations to such conventional techniques. For example, nickel is the preferred metal for creating an embossing tool to transfer the holographic interference pattern. Accordingly, only material softer than nickel can be imprinted by the die. For example, nickel can be used for imprinting on polyester films, soft plastics and the like. However, even with such soft material nickel deforms after continuous use so that after a few thousand meters of embossing, the embossing tool deteriorates to the point that it is no longer suitable for turning out copies.

Also, when a die is wrapped around a printing cylinder or roller, a seam runs approximately parallel to the axis of the cylinder. For the sake of accuracy, the holographic pattern cannot be located anywhere near the seam. In particularly large printing cylinders, multiple shims are used since it is often very difficult to make shims large enough for some embossing rollers. The chief problem with this situation is that there is a mark in the material every time that this seam comes around as a result of the rotation of the roller. As a result, a good deal of the roller surface is lost for practical use, and the size of the hologram that can be printed is severely limited. Since it is very difficult to make a solid cylindrical roller by a metal deposition process, such as electroplating, this problem probably cannot be

solved using conventional techniques, which are not adaptable to creating a seamless roller.

Other, harder materials have been tried in the production of embossing tools. For example, aluminum has been used for embossing dies for holographic transfer. However, the process for making the aluminum die is severely limited by the chemical etching process so that accuracy of the etched pattern degrades rapidly with increasing depth of the etching. Also, aluminum is not a particularly good material for extremely high pressures, such as those used in creating embossed holograms.

Other, harder materials have been used. For example ion milling or etching has been used to create holographic patterns on such materials as tool steel, diamond or chromium. One example of such a technique is found in U.S. Patent No. 5,521,030 to McGrew. This patent discloses the use of anisotropic reactive-ion etching to transfer a holographic interference pattern from a photoresist to the durable material to be used as an embossing tool.

Unfortunately, such techniques for forming holographic interference patterns on durable materials are extremely expensive and complex to carry out. Such techniques are only justified when large numbers of accurate holograms have to be embossed. Otherwise, the expense of such techniques can not be justified.

Further, none of the conventional techniques are capable of providing for seamless embossing, or any of the advantages associated therewith. Accordingly, there is still a need to inexpensively create embossing tools on hard material that can be used to transfer holographic interference patterns under conditions of high pressure without degrading the resultant copies, even for extended production runs.

Summary of the Invention

Accordingly, it is a first object of the present invention to eliminate the drawbacks of conventional embossing of data.

It is a second object of the present invention to provide an embossing tool which avoids the limitation of conventional seams on embossing rollers.

It is another object of the present invention to streamline the embossing process when transferring photo-profilable data.

It is a further object of the present invention to decrease the expense of transferring photo-profilable data.

It is an additional object of the present invention to eliminate steps in conventional embossing of photo-profilable data.

It is still another object of the present invention to limit the number of materials used in an embossing operation for transferring photo-definable data and

other materials.

It is yet a further object of the present invention to provide an embossing process in which the embossing surface can be selected from a wide variety of different hardnesses.

It still an additional object of the present invention to provide an embossing tool which avoids the limitation of conventional seams on embossing rollers.

It is still a further object of the present invention to provide an easily manufactured embossing surface capable of enduring high pressure for extended production runs.

It is again another object of the present invention to provide an embossing system using a photo-profilable material having good selectivity.

It is still a further object of the present invention to provide an embossing system having a photo-profilable material that does not have to be etched.

It is again another further object of the present invention to provide an embossing system having a photo-profilable material with excellent cured filmed properties.

It is yet an additional object of the present invention to provide an embossing system using a photo definable material having high resolution and high exposure sensitivity.

It is again a further object of the present invention to provide an embossing system using a photo-profilable material and embossing surface as a single entity.

It is yet another object of the present invention to provide an embossing system having a positive acting photo-profilable material.

It is still another object of the present invention to provide an embossing system having a photo-profilable material that is capable of processing with positive resist developers, and provides positive tone.

It is again another object of the present invention to provide an embossing system in which the hardness of the embossing surface can be easily varied.

It is still an additional object of the present invention to provide photodefinable surface suitable for casting operations.

It is still a further object of the present invention to provide a photodefinable embellishment coating material.

It is again another object of the present invention to provide a photoprofilable data transfer material capable of transferring a wide range of holographic data, including those constituted by translucent films viewed with laser light, defraction patterns, "2D" "3D" stereograms, true "3D" holograms or virtually any other holographic pattern admitting to transfer.

It is still another object of the present invention to provide an embossing system whereby metallic elements can be eliminated.

It is yet another object of the present invention to provide an embossing system in which photodefinable material can be negative acting as well as positive acting, and can be developed by non-aqueous as well as aqueous solvents.

It is again a further object of the present invention to provide a data transfer system which uses a polyimide casting material.

These and other goals and objects of the present invention are provided by an embossing surface configured for transferring data to other surfaces, where the embossing surface consists of a photodefined polyimide material.

A second embodiment of the present invention is manifested by a method of embossing data from an embossing surface to other surfaces. The method consists of the steps of exposing a photodefinable material to EMF radiation defining the data. Afterwards, the photodefinable material is cured to achieve an embossing surface of a selected hardness. Finally, the embossing surface is used to emboss the data onto other surfaces.

Brief Description of the Drawings

Figure 1(a) is a perspective view depicting the transfer of polyimide material onto an embossing roller.

Figure 1(b) is a perspective diagram depicting the precuring phase of the polyimide material.

Figure 1(c) is a perspective diagram depicting the photo defining of the polyimide material on the roller.

Figure 1(d) is a perspective diagram depicting the hardening phase prior to embossing.

Detailed Description of the Preferred Embodiments

The present invention includes the use of a photodefinable or photoprofileable, positive-acting (positive tone) polyimide as an embossing surface. The polyimide is treated as depicted in Figures 1(a) -1(d), and as described *infra* for the purpose of the present invention. The polyimide material is placed on an appropriate surface, heat-treated, exposed to EMF radiation (such as coherent light), and hardened into an embossing surface. Then the embossing surface is used to transfer data expressed as the EMF radiation to another surface. This technique for using polyimide material is particularly effective for creating a holographic master to be used as an embossing surface.

Because of the characteristics of the polyimide material, it is also suitable for use as a gravure printing surface. Such a surface is created using photo detection techniques, and a flash application of metal to provide a printing surface.

The positive photoresist characteristics of the polyimide material make this second embossing embodiment possible without the complications of conventional gravure printing processes, such as etching.

The polyimide material could be coated on virtually any surface, profiled, and then hardened to be used as a decorative or display surface. The use of such materials provides an advantage for artists since no material currently exists that can be easily formed, while still withstanding cleaning and ultraviolet radiation. Accordingly, the subject polyimide material can be used on any surface that could withstand the necessary curing temperatures.

The polyimide material can also be used in a casting operation to transfer the grooves of an existing hologram onto the polyimide material. Then, the pattern in the cast polyimide can be applied to other surfaces. Virtually any kind of casting technique can be used with the polyimide materials, examples of which are described *infra*.

The polyimides, which are applied to the novel uses in the instant application, are high temperature engineering polymers originally developed by the DuPont Company. When compared to most other organic or polymeric materials, polyimides exhibit an exceptional combination of thermal stability ($>500^{\circ}\text{C}$), mechanical toughness and chemical resistance. In addition, they have

excellent dielectric properties.

Conventionally polyimide films are frequently used as a "stress buffer" or protective overcoat for semiconductors. Polyimide stress buffers are typically 4-6 microns in thickness, and protect the delicate thin films of metal and oxides on the chip surface from damage during handling and from induced stress after encapsulation in plastic molding compound.

When used as a photo-definable material, patterning is simple and straightforward. Because of the low defect density and robust plasma etch resistance inherent with polyimide films, a "single mask" process can be implemented.

In the conventional fabrication of microelectronic devices, photodefinable polyimides are typically applied as a liquid onto a substrate, and then thermally cured into a smooth, rigid, intractable polymeric film or structural layer as further described, *infra*. The film can be patterned using a lithographic (photographic) process in conjunction with liquid photoresists. "Photodefinable" polyimides are light-sensitive and readily patterned without the use of photoresists, further simplifying the fabrication process.

For purposes of demonstrating the effectiveness of the present invention, the photodefinable, positive-acting polyimide selected is HD-8000, a product of

HD Microsystems™, a joint enterprise with Hitachi Chemicals and DuPont Electronics. HD-8000 is a positive-tone, aqueous developing, photodefinable polyimide for stress buffer and chip bonding applications. HD-8000 includes a polyamic acid back-boned precursor that is synthesized by reacting aromatic dianhydrides with aromatic diamines. Also included are photosensitizers to provide positive tone lithographic properties during processing. Solvents are included as well. This material achieves pattern definition which greatly exceeds that of earlier-generation aqueous developing products.

The aforementioned polyimide material is positive tone or positive acting and can be developed with an aqueous solution. However, this merely one example of the type of polyimide material that can be used with the present invention. For example, a negative tone or negative acting polyimide can also be used depending upon the exact implementation of data transfer to which the material will be put. Also, the polyimide material that is developed with non-aqueous solutions can also be used for purposes of the present invention.

In Figure 1(a) the polyimide material 1 is arranged using an applicator 2 on the moveable surface such as coating roller 3. The application of the polyimide material forms a coating 4 on the roller. It should be noted that while a roller is used in the example of Figure 1(a), other surfaces can also be used for the

application of polyimide material for photo defining and later embossing operations.

In most microelectronic applications polyimide coatings are typically spin applied to the substrate. This same process and basic tool set is also used to apply liquid photoresists. For optimal adhesion to silicon, oxides and most metals, adhesion promoters are required. Some polyimides have built in adhesion promoters, while others require the application of a separate adhesion promoter or coupler prior to polyimide application. Adhesion promoters are also applied by spin coating.

While spin coating assures the best uniformity and coating quality, other application techniques that have been used for applying polyimides include draw, spray, extrusion, roller, dip and drop coating.

While a rotating cylinder 3 has been used for coating 4, other shapes of embossing surfaces can also be used. For example, a flat surface can be used with a platen moved in two directions, or even a platen that moves in one direction while the source of EMF radiation is also moving in one or more directions.

It should be noted that the data to be transferred by means of the present invention can be expressed in a wide variety of different configurations. For example, holograms are of particular interest, and the transfer of holograms is

easily facilitated by the present invention. Such holograms can include translucent films viewed with laser light, defraction patterns, "2D" "3D" stereograms, true "3D" holograms, as well as virtually any other holographic format for arrangement can be transferred using the present invention. It should be further noted that the present invention is not limited to the transfer of holographic material. Rather, virtually any other type of data that can be transferred by means of embossing can be quickly and accurately transferred using the system of the present invention.

In Figure 1(b), the roller 3 with its polyimide coating 4 is placed in a curing oven 5. In the alternative, the coated substrate could be heated or soft; baked on hot plates at 120°C for approximately 130-260 seconds. This is done for a target fixed thickness of 10 microns. However, different target thicknesses will require different baking times. After the pre-cure operation has altered the polyimide material 4 to a predetermined thickness and consistency, the polyimide material is ready for alteration or profiling by electromagnetic EMF radiation, such as light.

Coated substrates should be cooled to ambient temperature prior to EMF exposure. A chill plate is recommended for cooling after the heat treatment. For improved control, the wafers should be held for a minimum of 20 minutes prior to exposure. The coated substrates can be stored for up to 72 hours in a wafer

cassette box under clean room conditions prior to exposure and development.

In Figure 1(c) the light is monochromatic and provided by laser 6. It should be noted that while one preferred embodiment as depicted in Figure 1(c), uses a laser light source, other forms of electromagnetic radiation can be used. Examples are : light having plural frequency elements, x-rays, radio waves, ultraviolet light, electron beams and infrared light. Photosensitive polyimides permit the patterning of relatively fine features. An aspect ratio of 1 to 1 can be achieved in fully cured films.

Data (from a source not shown) is expressed by the light from laser 6, and is used to profile or otherwise define or modify the polyimide coating 4 on roller 3. On example of such a photo defining technique is the pixel-by-pixel method disclosed in U.S. Patent No. 5,822,092, to Davis issued October 13, 1998, and incorporated herein by reference.

Part of the light profiling of the polyimide material 4 is the development of the material that has been exposed or otherwise profiled by the incident electromagnetic radiation, such as coherent light. In the preferred embodiment depicted in Figures 1(a)-1(d), a well-known type of aqueous solution is used to develop the exposed polyimide material. This can be carried out using a number of different techniques. For example, the entire roller 3 can be submerged in a

bath (not shown). In the alternative, a developing chamber (not shown), similar to the heat treatment chambers, can be used to apply the developing solution.

However, any other technique used for developing, using either aqueous or non-aqueous developing solutions are also suitable for the present invention. Any known combination of radiation exposure and development effective for any polyimide is suitable for the Figure 1 (c) operation of photoprofiling of the polyimide material.

After being profiled by the light from laser 6, and developed, the polyimide coating 4, arranged on roller 3 is heat-cured, for example in another oven 7. The curing takes place according to the parameters specified in the Preliminary Product Bulletin by HD Microsystems™, entitled *Photo Definable Image HD-8000 Series Positive Tone, Aqueous Developable Polyimide*, attached hereto as Appendix 1.

Curing the polyimide film involves the removal of the solvent carrier or other volatiles from the layer and the imidization or hardening of the polymer into an intractable polyimide film. This curing process is typically done in steps. Hot plates are commonly used for the initial heat treatment or bake (Figure 1(b)) after the polyimide application. The initial application can range from 50°C to 150°C on one or more in-line hot plates. A furnace or programmable oven is used for the

final cure (Figure 1(d)). Final curing is usually done between 280°C - 400°C depending on the application.

The objectives of a proper cure schedule are to: 1) remove residual solvents, 2) complete the imidization process, 3) complete the adhesion process. Because all three of these actions can occur simultaneously at a given temperature, the cure schedule is a very important process step which can impact cured film quality and associated mechanical properties.

The following variables need to be considered in curing polyimide films: curing tool; atmosphere; loading temperature; ramp rate; soaks (holding temperatures); final cure temperature; and, ramp down.

Curing is typically done as a batch process using programmable ovens or furnaces. (Single-wafer curing tools that utilize a series of hot plates have also been developed for in-line processing. This technique has been frequently used with non-photo-definable polyimides.)

Curing should be performed under a nitrogen atmosphere (oxygen conc. <100ppm). Some programmable ovens are designed to cure under a vacuum. A partial vacuum may be used with a nitrogen atmosphere.

Loading temperatures, ramp rate, soaks (intermediate holding temperatures), final cure temperature and cool down rate can be optimized for optimum

throughput and cured film properties. A basic cure schedule is given for a typical “single-mask” stress buffer application : load into oven or furnace at $<150^{\circ}\text{C}$; ramp from loading temperature to 350°C over a 60 minute period; hold at 350°C for 30 minutes; and , substrates can be unloaded immediately or allowed to cool down. It should be noted that the curing can also be done in an oven without the special atmosphere. The selection of oven atmosphere depends upon a number of factors, such as the size of the area of the polyimide to be cured, the thickness of the final polyimide coating, and the other curing factors.

While one type of polyimide has been described, and proven to work, this is merely one example of the various photo-definable, polyimide materials that can be used to constitute the embossing system of the present invention. Further, such materials are particularly appropriate for transferring dot matrix holograms.

Based upon the aforementioned specification, the polyimide can be cured to a predetermined hardness and thickness on roller 3. Because the polyimide material forming layer 4 can be cured to a predetermined hardness, it is possible to use the polyimide surface 4 as an embossing surface. Consequently, the formation of a conventional metal embossing surface for transferring holograms is not necessary with the present invention. The result is a substantial saving of time and expense.

Because the polyimide used in the preferred embodiment can be used as a positive exposure substance, the material can also be used for gravure printing, in which the printed material is formed as depressions around unprofiled photoresist material. The ink is placed within the grooves that constitute the letters or the images, and the paper or other transfer surface is forced on the profiled surface so that the ink in the depressions is forced onto the transfer surface. The polyimide material is capable of being cured to a consistency that will handle the pressure handled for gravure printing operations. It should be noted that the roller 3 depicted in the drawings need not be used in this printing process. Rather, a flat platen can be used in the alternative. However, it should be noted that most printing takes place in roll presses so that roller 3 would most likely be the preferred surface for this type of system.

The use of polyimide for gravure printing requires a flash coating of a metal, such as nickel or chrome to be placed on the polyimide coating. However, the acid wash that is used in more conventional photodefining preparatory to gravure printing, is not necessary. As a result, the acid used in such washes will not degrade the metal defining the data to be transferred. Accordingly, the present invention avoids the loss of clarity or accuracy, as well as size limitations, inherent to conventional gravure printing systems. Accordingly, gravure printing

using the polyimide in accordance with the present invention is carried out more easily and more cheaply than conventional systems, and results in a better product.

The polyimide material can be used in another embodiment to copy the interference pattern of a hologram, or any other data in a relief pattern. This is done by forming a casting of the polyimide material over a holographic master. As a result, a impression of the diffraction grating pattern is made on the casting material. The casting is then used to transfer the data from the holographic master to other surfaces. In so doing, the benefits previously described with respect to the polyimide material are achieved for copies made from the polyimide casting.

While a number of embodiments have been described by way of example, the present invention is not limited thereby. Rather, the present invention should be interpreted to include any an all variations, modifications, permutations, adaptions, and embodiments that would occur to one skilled in this art once having been taught the invention. Therefore, the present invention is to be limited only by the following claims.

Claims

I claim :

1. An embossing surface configured for transferring data to other surfaces, said embossing surface consisting of a photodefined polyimide material.
2. The embossing surface of claim 1, wherein said polyimide is aqueous developable.
3. The embossing surface of claim 2, wherein said data is transferred to said embossing surface by photo detection.
4. The embossing surface of claim 3, wherein said data is text.
5. The embossing surface of claim 3, wherein said data is image data.
6. The embossing surface of claim 3, wherein said polyimide is hardened by baking.

7. The embossing surface of claim 3, wherein said polyimide is defined to be positive tone.

8. The embossing surface of claim 7, further comprising a flash-coated metal film over said polyimide.

9. The embossing surface of claim 8, wherein said embossing surface is suitable for gravure printing.

10. A method of embossing data from an embossing surface to other surfaces, said method consisting of the steps of :

(a) exposing a photo-definable material to EMF radiation defining said data;

(b) curing said photo-definable material to achieve an embossing surface of a selected hardness; and,

(c) using said embossing surface to emboss said data onto said other surfaces.

11. The method of claim 10, wherein step (a) comprises a subsequent substep of :

(i) developing said photo-definable material with a solvent.

12. A method of claim 11, wherein step (a), further comprises a preliminary substep of :

(ii) applying said photo-definable material to a roller.

13. The method of claim 12, wherein step (a) further comprises a preliminary substep of :

(iii) pre-curing said photo-definable material by heating.

14. The method of claim 10, wherein said photo-definable material is a polyimide.

15. The method of claim 10, wherein said step (c) of curing comprises heating said photo-definable material.

16. The method of claim 10, wherein said EMF radiation comprises light.

17. The method of claim 16, wherein said light is monochromatic and generated by a laser.

18. The method of claim 15, wherein step (c) comprises a preliminary substep of :

(ii) applying a coating of metal over said polyimide material.

19. The method of claim 18, wherein said step (c) of using said embossing surface to emboss said data is carried out as gravure printing on said other surfaces.

20. The method of claim 19, where the photo-definable material is copied by electroforming using nickel.

21. The method of claim 19, wherein said photo-definable material is copied by electroforming using chrome.

22. The method of claim 10, wherein said data is selected from a group consisting of images, printed text, reliefs and holograms.

23. The method of claim 22, wherein said data is in a holographic dot matrix format.

24. The method of claim 10, wherein said photodefinable material is applied to a flat surface.

25. The method of claim 10, wherein said photodefinable material is applied as an embellishment coating to an object.

26. A method of transferring data from a first surface to other surfaces to a transfer medium, said method consisting of the steps of :

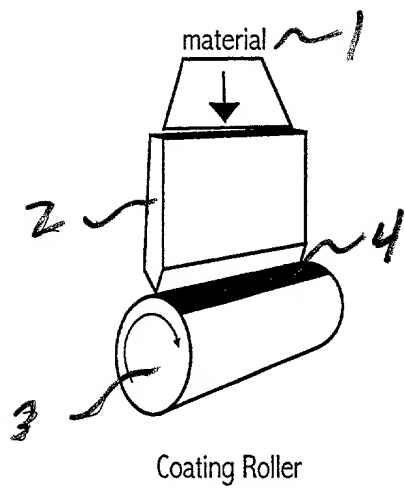
- (a) casting said transfer medium on a surface containing said data; and,
- (b) using said transfer medium to emboss said other surfaces.

27. The method of claim 26, wherein said transfer medium is polyimide.

Abstract

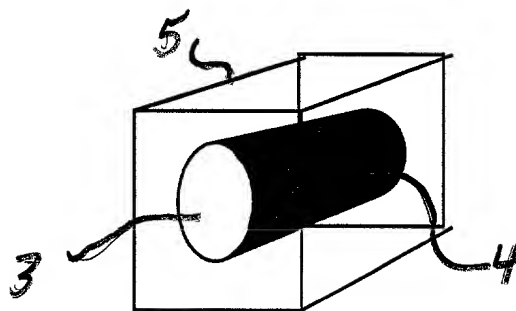
PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING SURFACE

An embossing surface and a method for creating that surface is provided by a polyimide material which has photodefinable characteristics. One benefit is that the embossing surfaces do not have to be made by data transfer from the photodefinable surface. The polyimide material is cured by heating to a predetermined hardness appropriate for the surfaces to be embossed.



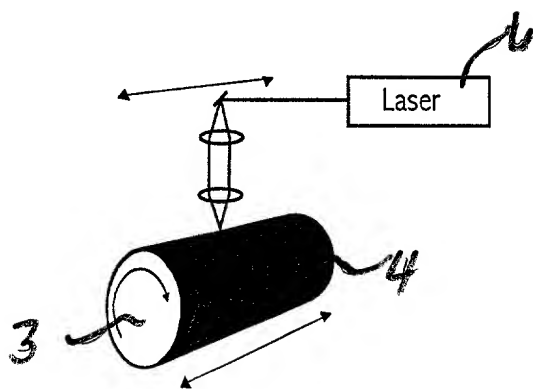
Coating Roller

FIGURE 1(a)



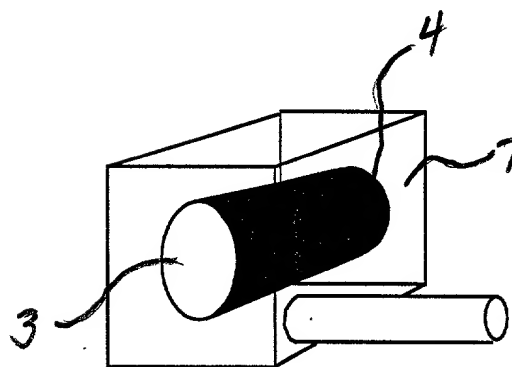
Pre-cure

FIGURE 1(b)



Direct Write Dot Matrix.

FIGURE 1(c)



Harding post Cure

FIGURE 1(d)

Application for United States Patent

Declaration and Power of Attorney

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled PHOTO DEFINABLE POLYIMIDE FILM USED AS AN EMBOSSING SURFACE the specification of which:

[x] is attached hereto

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, ' 1.56(a).*

I hereby claim foreign priority benefits under Title 35, United States Code, ' 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

<u>Prior Foreign Application(s)</u>	<u>Country</u>	<u>Day/Month/Year Filed</u>	<u>Priority Claimed</u>
N/A			

I hereby claim the benefit under Title 35, United States Code, ' 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, ' 112. I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, ' 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>Application Serial Number</u>	<u>Filing Date</u>	<u>Status (Patented, Pending, Abandoned)</u>
----------------------------------	--------------------	--

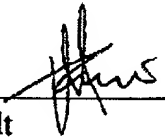
Power of Attorney: As the named inventor, I hereby appoint as Robert G. Lev;

registration number 30,280 of Lev Intellectual Property Consulting 4766 Michigan Boulevard Youngstown, Ohio 44505, as attorney to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

All correspondence should be directed to Robert G. Lev c/o Lev Intellectual Property Consulting 4766 Michigan Boulevard Youngstown, Ohio 44505. All phone Telephone calls should be directed to Robert G. Lev (330) 759-1423.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

(1) Inventor : Ken Harris

Signature: 

Date : Oct - 18, 2000

Post Office : 2875 Boldt

City, State, Zip : Las Cruces, New Mexico 88008

Citizenship: U.S.

*Title 37, Code of Federal Regulations, ' 1.56(a):

A duty of candor and good faith toward the Patent and Trademark Office rests on the inventor, on each attorney or agent who prepares or prosecutes the application and on every other individual who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application. All such individuals have a duty to disclose to the Office information they are aware of which is material to the examination of the application. Such information is material where there is substantial likelihood that a reasonable examiner would consider it important in deciding whether to allow the application to issue as a patent. The duty is commensurate with the degree of involvement in the preparation or prosecution of the application.

Appendix I



HD Microsystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

PRELIMINARY PRODUCT BULLETIN

Photodefinable HD-8000 Series Positive Tone, Aqueous Developable Polyimide

Table of Contents

1. Introduction	2
2. Product Description	2
3. Storage and Availability	3
4. Safety and Handling	3
5. Processing	3
5.1 Clean Room Conditions	3
5.2 Substrate Preparation	3
5.3 Spin Coating Process and Film Thickness	3
5.4 Soft-Bake Process	4
5.5 Exposure Process (Exposure Dose, Focus)	4
5.6 Single Wafer Development Processing	6
5.7 Resolution	7
5.8 Hold-Time Latitude	10
5.9 Cure Process	11
5.10 Rework	11
6. Cured Film Properties	12
6.1 General Properties	12
6.2 Cured Film Properties as a Function of Cure	12
6.3 Optical Properties	13
6.4 Residual Stress	14
7. Dry Etch Resistance	14
8. Package Reliability	15
9. Appendices	15
9.1 Appendix A	15
9.2 Appendix B	16
9.3 Appendix C	17
9.4 Appendix D	18
Summary	19
Technical Service	19

1. Introduction

HD-8000 is a positive-tone, aqueous developing, photodefinable polyimide for all stress buffer and flip chip bonding applications. This product can be readily processed using standard I-line, G-line and broad band lithography tools and common TMAH-based developer tracks. HD-8000 utilizes a newly developed, fully aromatic, polyimide backbone. Cured films have the corresponding thermal and mechanical stability associated with polyimide materials. New photopolymer technology was utilized to achieve pattern definition which greatly exceeds that of earlier-generation aqueous developing products. The resolution capability of HD-8000 should meet or exceed the requirements of all contemporary semiconductor target applications.

2. Product Description

HD-8000 is a positive tone, self-priming, I-line, G-line and broad band photodefinable polyimide precursor that can be patterned to cleanly resolve micron scale relief patterns with controlled size and side-wall profiles without the need for photoresist. Because of this unique combination of properties, HD-8000 reduces the number of process steps required for patterning polyimide overcoat layers. Its fine line resolution and inherent durability as a dry-etch mask make it ideal for most "single-mask" applications.

In a "single-mask" stress buffer process, the polyimide stress buffer layer or (secondary passivation layer) is also used as a resist layer to pattern the underlying silicon nitride primary passivation.

Key Features:

- Positive tone
- Process with positive resist developers
- "NMP-free" formulation (compatible with chemical amplification resists)
- High exposure sensitivity
- High resolution
- Wide process latitude
- Good room temperature (RT) viscosity stability
- Excellent cured film properties
- Good selectivity in dry etch processing
- Wide process latitude from soft-bake to exposure and exposure to develop

HD-8000 is supplied as a liquid coating and typically packaged in 1 or 4 liter high-density polyethylene or polypropylene bottles. The solution properties for HD-8000 are shown in Table 1.

Table 1. Liquid properties (typical values)

Item	Condition	Units	HD-8000
Viscosity	25°C (E-type)	cPs	1500±100
Non-volatile content	200°C/1hr +350°C/1hr	%	38±1
Water content	Karl Fisher	%	<0.5
Metal impurity	MIP-MS (Hitachi P-7000)		
Na		ppm	<1.0
K		ppm	<0.5
Cu		ppm	<0.5
Fe		ppm	<0.5
U		ppb	<0.5
Th		ppb	<0.5
Chloride*	Ion chromatography	ppm	<2
Particles	LPC (Rion KL-01)	/ml	<5000

*Extracted from cured film

3. Storage and Availability

HD-8000 is formulated to provide a 5-10 μm cured film thickness under nominal process conditions as described in Table 2. HD-8000 solutions should be stored in a freezer at -18°C upon receipt for long-term storage; room temperature (RT) stability is 2 weeks. Stored solutions should be allowed to warm up to room temperature before opening to avoid moisture condensation on the inside of the bottle. To avoid solvent loss, bottles should be kept tightly sealed when not in use.

4. Safety and Handling

During handling of HD-8000, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. Solvent-resistant gloves, goggles and safety masks should be utilized; consult the individual product Material Safety Data Sheet (MSDS) for additional toxicity/health hazards information.

5. Processing

5.1 Clean Room Conditions

The processing of HD-8000 should be performed in standard clean room conditions under yellow light. Temperature and relative humidity conditions should be controlled for consistency ($\pm 2.0^{\circ}\text{C}$, $\pm 2\%$ RH) to obtain the best processing results.

5.2 Substrate Preparation

Substrates should be clean and dry prior to use. In some cases, oxygen plasma cleaning followed by a wet cleanup with an organic stripper solution such as Tokyo Ohka S-106 to remove trace organic contaminants is recommended during rework. (Trace organic contaminants can degrade adhesion to the substrate during processing or after curing.)

5.3 Spin Coating Process and Film Thickness

Nominal process conditions for HD-8000 are shown in Table 2. The volume of solution dispensed should remain constant for each wafer to ensure wafer-to-wafer uniformity. Low spin speed and/or short spin times can impact film uniformity; the recommended spin speed range is 1,000-4,000 rpm. The recommended spin time is 30-60 seconds.

A spin speed curve for HD-8000 is shown in Figure 1. The standard deviation for a soft-baked film on an 8 inch wafer can be as low as $0.2 \mu\text{m}$. The actual coating thickness obtained for a given set of spin coating conditions will depend on a number of parameters such as equipment type, wafer size, surface topography, ambient conditions and soft-bake conditions. Refractive indices together with Cauchy coefficients for measuring coating thickness are given in Table 3 for pre-cured and cured films of HD-8000. A film thickness reduction of approximately 15-25% can be expected after development; approximately 43-47% after final cure (as compared to original soft-bake thickness).

Table 2. Processing conditions*

Process		Units	Target Thickness			Product Code	Process Tool
			5 microns	8 microns	10 microns		
Coating	Pre-spin	rpm/sec	1000/5	1000/5	1000/5	HD-8000	TEL Mark 7
	Spin	rpm/sec	3400/30	1900/30	1390/30		
Soft-bake**		°C/sec	120/130	120/180	120/260		
Soft-baked thickness		microns	9.4	14.7	18.7		
Exposure	Dose	mJ/cm²	240	500	700		Cannon
	Focus	microns	0	0	0		FPA 3000iw
Development	Puddle 1	sec	35	60	90	2.38% TMAH	TEL Mark 7
	Puddle 2	sec	35	60	90	at 23°C	
	Rinse	rpm/sec	1000/10	1000/10	1000/10	DI Water	
	Spin-dry	rpm/sec	3500/10	3500/10	3500/10		
Developed thickness		microns	7.2	11.5	15.2		
Post-bake		°C/min		150–350/60		N ₂	Diffusion tube
		°C/min		350/30		(O ₂ :100 ppm)	
Cured thickness		microns	5	8.2	10.8		

*See Appendix A

**Proximity bake temperature at 100μ

Figure 1. Spin speed vs. film thickness after soft-bake

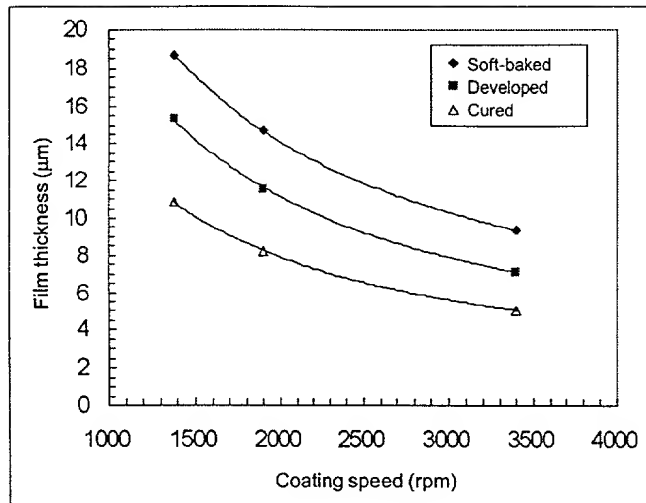


Table 3. Refractive indices for thickness measurements

Film	Refractive Index	Filter*
Soft-baked	1.551	R-60
Developed	1.550	R-60
Cured	1.618	R-60

*Short wave length sharp cut filter at 600 nm

Cauchy law on n and k

Film	N1	N2	N3	K1	K2	K3
Soft-baked	1.651	-1.172e-2	2.250e-3	2.813e-5	-9.527e-5	2.656e-5
Developed	1.656	-1.548e-2	2.462e-3	2.116e-5	-1.086e-4	2.645e-5
Cured	1.663	-1.033e-2	2.877e-3	-5.776e-4	3.735e-4	7.317e-5

$$n(\lambda) = N1 + N2/\lambda^2 + N3/\lambda^4 \quad k(\lambda) = K1/\lambda + K2/\lambda^3 + K3/\lambda^5 \quad \lambda(\mu\text{m})$$

5.4 Soft-bake Process

Primary Objectives: 1) to drive off carrier solvents from the polyimide coating and producing a tack-free surface for exposure; 2) to provide sufficient chemical resistance and adhesion so that the unexposed areas of the coating will not be attacked or delaminated by the developer. Coated substrates should be soft-baked on one or more hot plates at 120°C (proximity mode) for 130–260 seconds. (In the contact mode the temperature should be re-adjusted downward to obtain the recommended film thickness after development.)

The substrates must remain in a horizontal (level) position during the soft-bake since the coating is still liquid after spin application.

Coated substrates should be cooled to ambient temperature prior to UV exposure. A chill plate is recommended for cooling after the bake. For improved CD control, the wafers should be held for a minimum of 20 minutes prior to exposure. The coated substrates can be stored for up to 72 hours in a wafer cassette box under clean room conditions prior to exposure and development. (See Section 5.7.) The effect of soft-bake temperature and times on photolithographic properties are given in Tables 4 and 5.

5.5 Exposure Process (Exposure Dose, Focus)

The amount of incident radiation required for optimum resolution and CD depends on the coating thickness (Figures 2 and 6), structure size, side-wall profile and feature uniformity. Again, for improved CD control, the wafers should be held for a minimum of 20 minutes prior to development. The coated substrates can be stored for up to 72 hours in a wafer cassette box under clean room conditions prior to development. (See Section 5.7.) Depth of focus will impact resolution and feature size; generally, focus latitude for the best resolution is +3.0 to -3.0 μm from the top of the film surface (Figures 3 and 4) CD control as a function of mask linearity is plotted in Figure 5.

Figure 2. Exposure sensitivity curves at various cured thicknesses

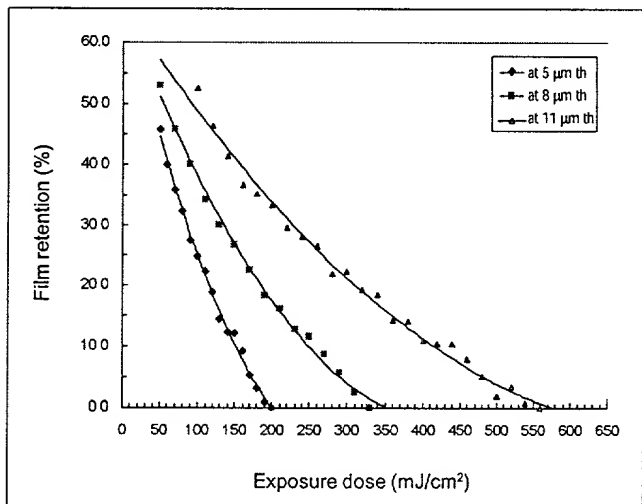


Figure 3. Effect of varying focus margin on resolution (5 μm cured)

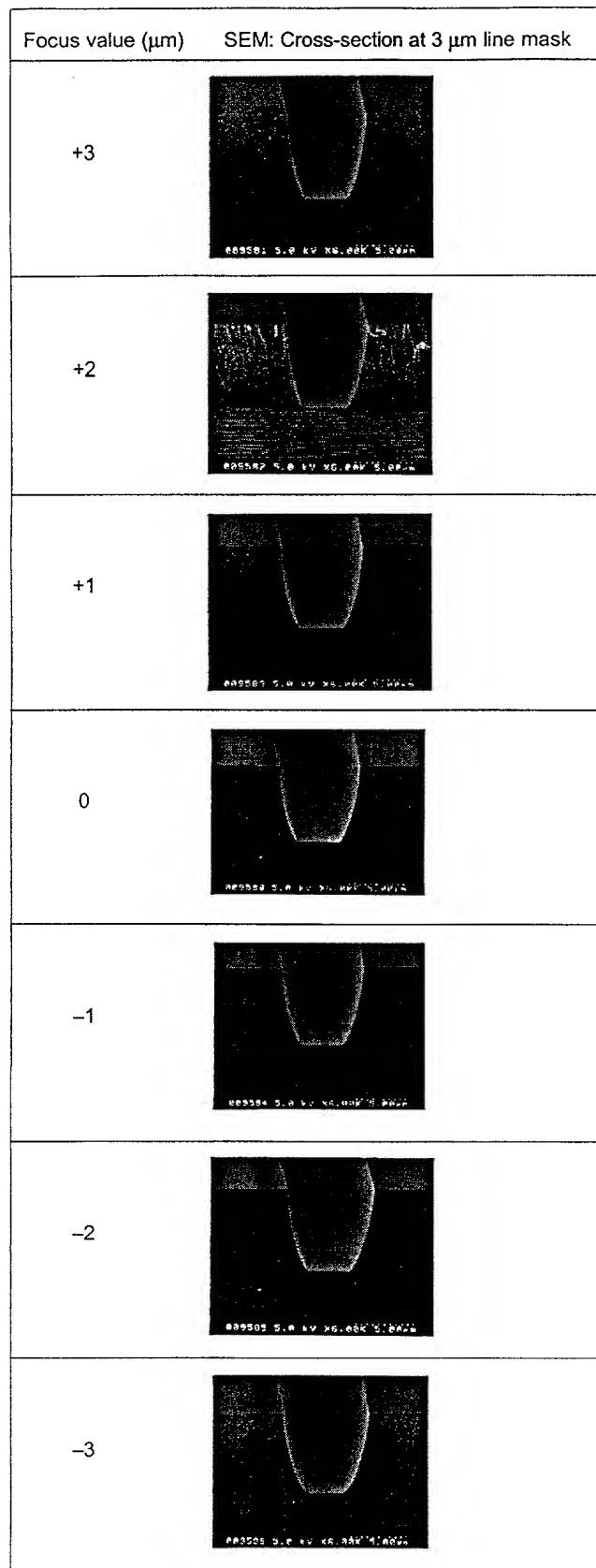


Figure 4. Effect of varying focus margin at various exposure energies on CD (5 μm cured)

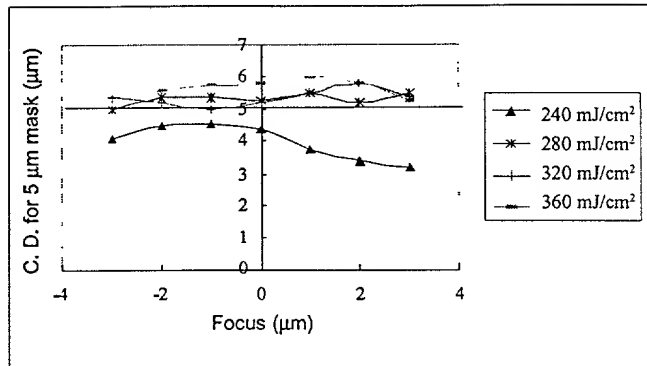
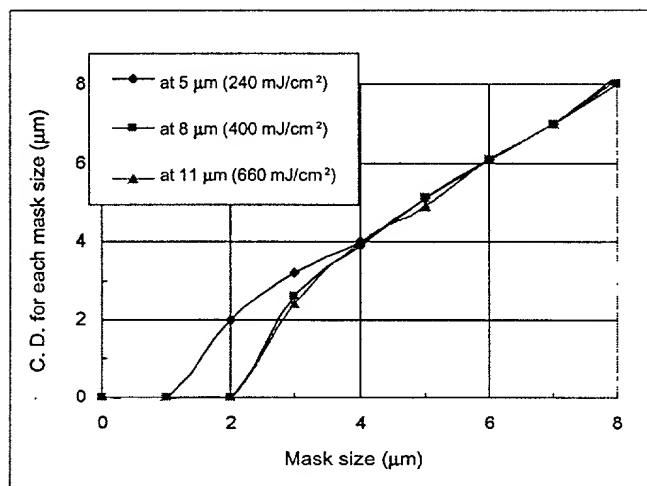


Figure 5. CD control as a function of mask linearity at various cured film thicknesses



5.6 Single Wafer Development Processing

After exposure the wafer can be developed on a standard, positive photoresist developer track using a standard TMAH-based positive photoresist developer with a normality of 0.25 to 0.27 (2.27 to 2.46%).

After exposure, it is recommended that HD-8000 be developed after a minimum hold time of 20 minutes. No post exposure bake is required. Exposed films can be held for up to 72 hr prior to development without significantly impacting resolution using a puddle development process.

In a typical single wafer puddle process, the wafer is positioned on the developer chuck and developer solution is puddled onto the stationary wafer for a set period of time. The developer solution is then spun off. A second puddle of developer is then dispensed for a set time period that is predicated by film thickness and general process conditions. Since the development process will continue as long as the polyimide coating is in contact with the developer, develop time is a critical factor in defining the parameters of a robust process (Tables 4 and 5). After development the wafer should be rinsed with water while the wafer is spun at a moderate rpm level. After rinse, the wafer is spun dry.

Figure 6. Exposure dose margin for a 5 μm square hole CD at various cured film thickness

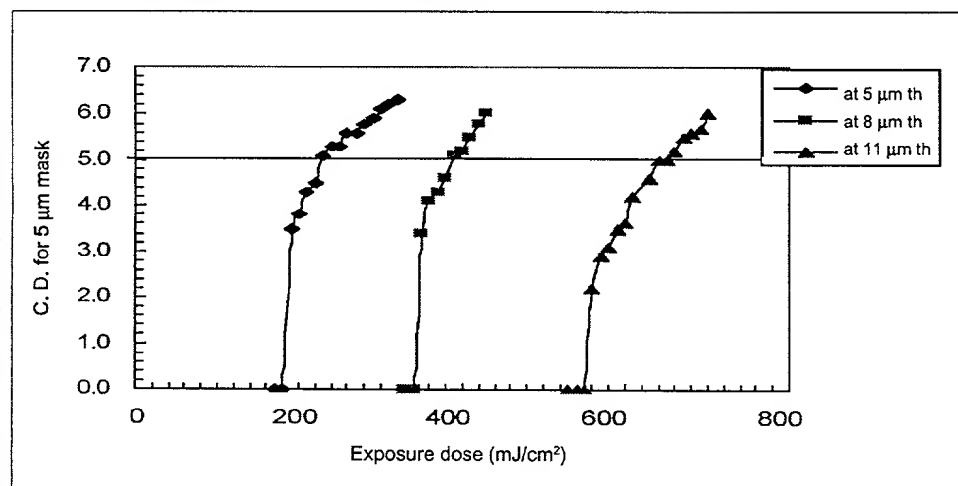


Table 4. Effect of soft-bake temperature on film retention and minimum exposure energy*

Soft-bake** (°C/sec)	Soft-bake thickness (micron)	Development time (sec)	Development thickness (micron)	Film retention (%)	Min. exposure energy (mJ/cm²)
114/170	12.6	50x2	9.4	74.3	280
116/170			9.7	76.9	300
118/170			9.9	79.1	350
120/170			10.4	81.5	370
120/170	12.6	35x2	10.8	85.5	570
		50x2	10.4	81.5	370
		70x2	9.5	75.2	270

*See Appendix B

**Proximity bake temperature at 100 μ

5.7 Resolution

Micrographs and SEM photographs illustrating resolution capability and side-wall profile for in 5 μ cured films are pictured in Figures 7-10

Resolution as a function of film thickness after development and after cure is illustrated in the micrographs pictured in Figure 11

The side wall profiles of soft-baked and cured films of HD-8000 as a function of film thickness are pictured in Figure 12

Feature size can be impacted by varying exposure conditions and other processing variables (Table 5)
Figure 13 plots film retention as a function of minimum exposure dose, using the conditions detailed in Table 5

Figure 7. Micrograph of developed film (5 μ m cured)

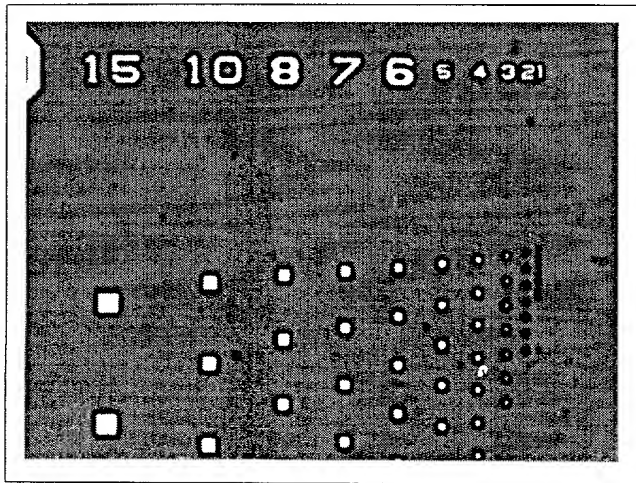


Figure 8. SEM photograph of developed film of 5 μ m line (5 μ m cured)

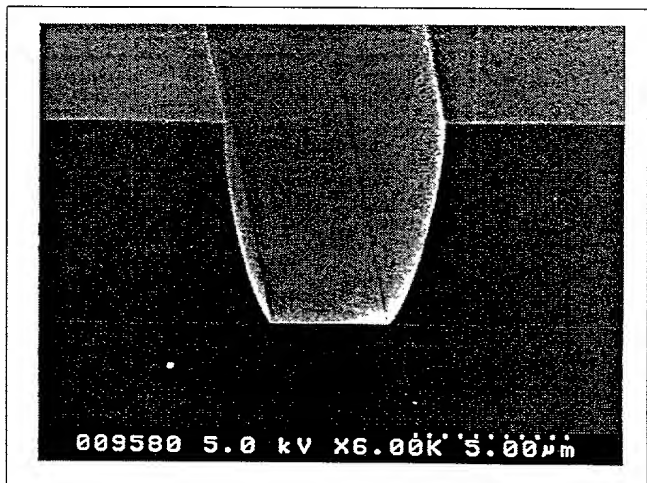


Figure 9. Micrograph of developed film (5 μ m cured)

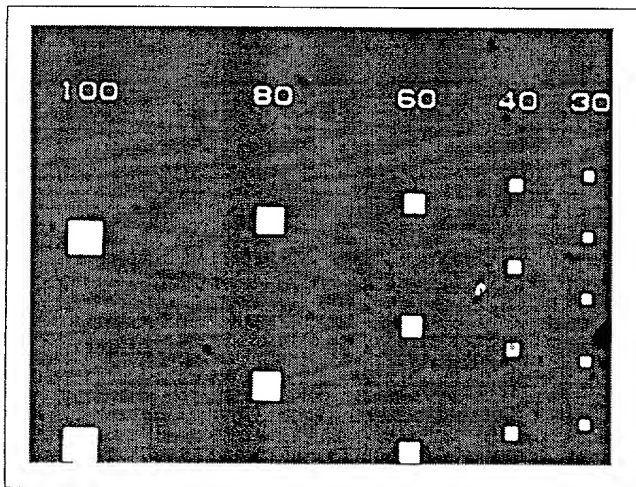


Figure 10. SEM photograph of cured film of 5 μ m line (5 μ m cured)

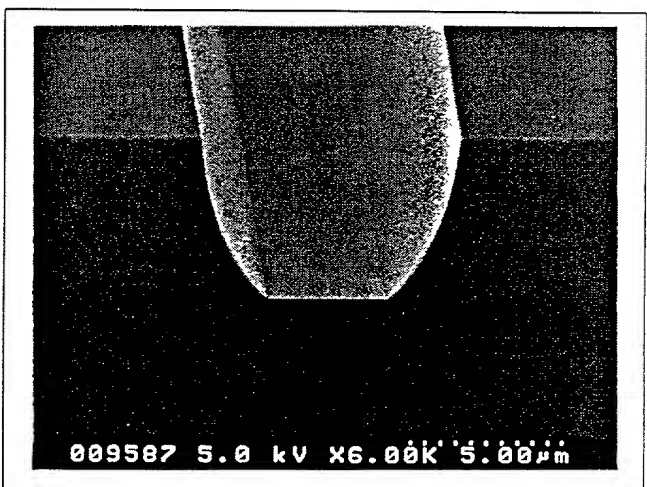


Figure 11. Micrographs depicting resolution after development (left) and after cure (right). For each picture, 1, 2, 3, 4, 5 and 6 μm square hole and space patterns are shown from the right to left side.

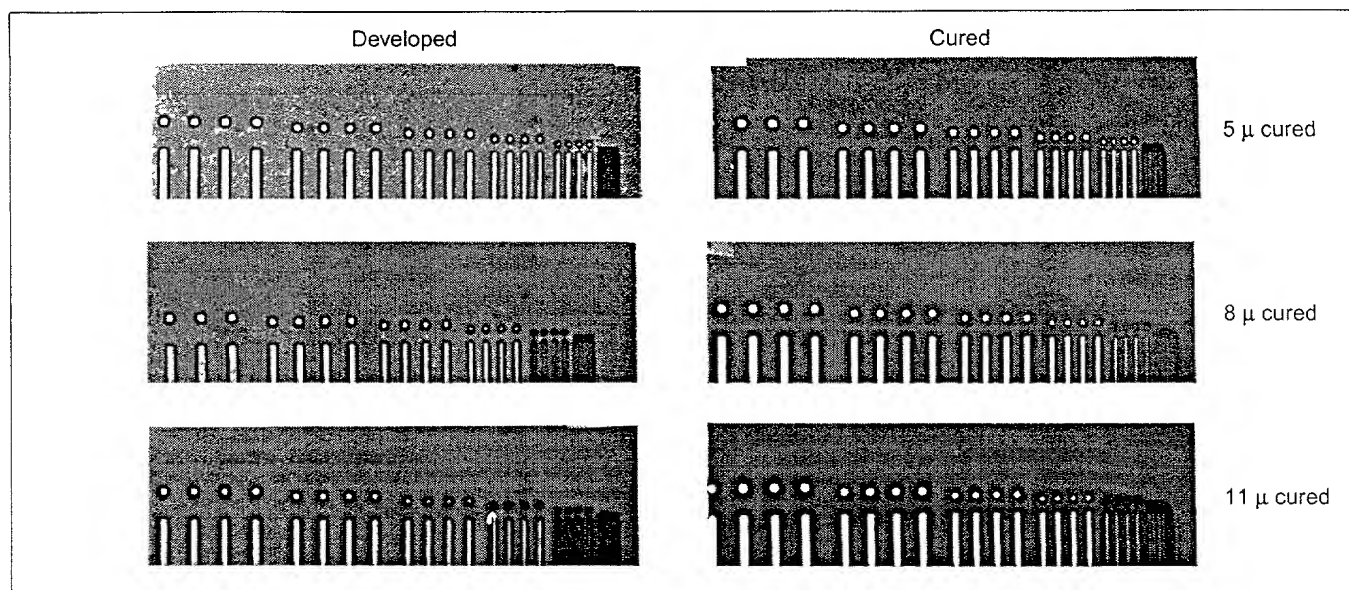


Figure 12. SEM photographs showing resolution after development (left) and after cure (right).

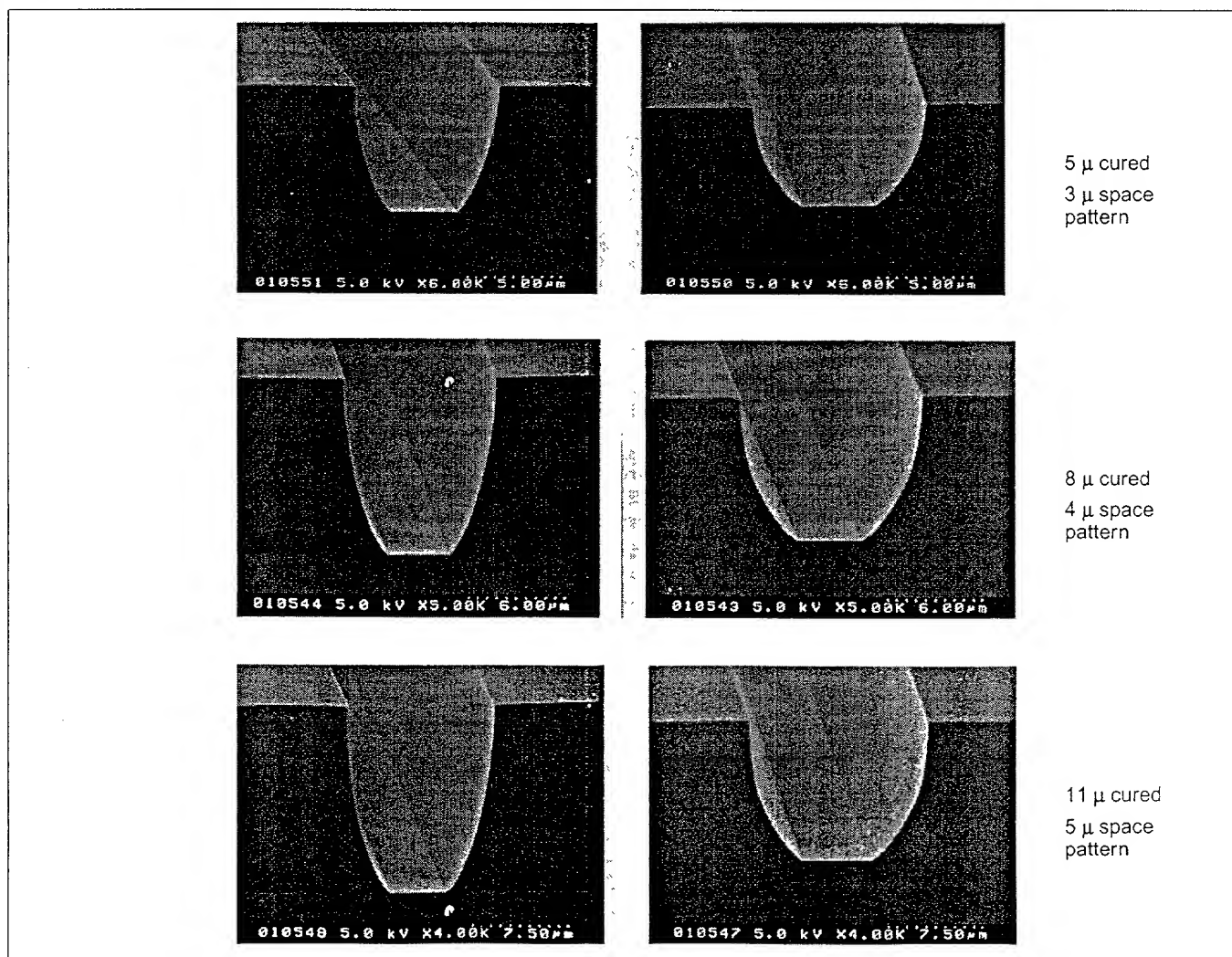


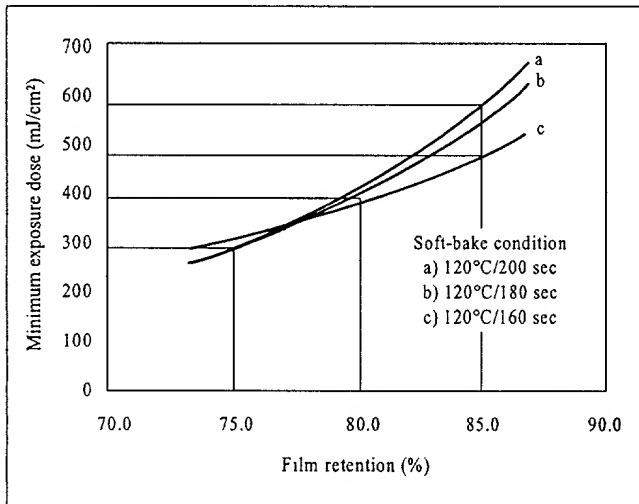
Table 5: Effect of soft-bake time and development time on photolithographic properties*

Spin speed (rpm)	Soft-bake** (°C/sec)	Film thickness after soft-bake (microns)	Dev. time (sec)	Film thickness after dev. (microns)	Film retention (%)	Minimum exposure (mJ/cm ²)	Film thickness after cure	10 micron line size
1350	120/160	14.6	90	12.3	84.5	480	8.7	11.1
			120	11.8	80.5	370	8.4	10.8
			150	11.3	77.3	340	8.0	10.6
			180	10.8	73.3	280	7.7	9.1
1350	120/180	14.6	90	12.5	85.8	600	8.9	10.7
			120	11.8	81.4	400	8.4	10.2
			180	11.5	78.7	360	8.2	10.4
			270	11.2	75.6	310	7.9	9.7
1350	120/200	14.7	90	12.7	86.9	690	9.0	10.4
			120	12.2	82.9	480	8.7	10.4
			150	11.7	79.4	380	8.3	10.5
			180	11.3	76.6	330	8.0	9.8

*See Appendices C and D

**Proximity bake temperature at 100 μ

Figure 13. Film retention vs. minimum exposure dose



5.8 Hold-Time Latitude

HD-8000 exhibits wide hold-time process latitude between soft-bake and exposure, as well as from exposure to development. After soft-bake, exposure or development, coated substrates can be stored for up to 72 hours in a wafer cassette box under clean room conditions prior to moving on to the next process step. Figures 14-17 compare minimum exposure energy, film retention and critical dimension control as a function of hold time. On non-linked tracks a hold time of 20 minutes after soft-bake and exposure is recommended for improved CD control.

Figure 14. Minimum exposure dose and film retention vs. hold time between soft-bake and exposure with 8 μm-cured standard condition

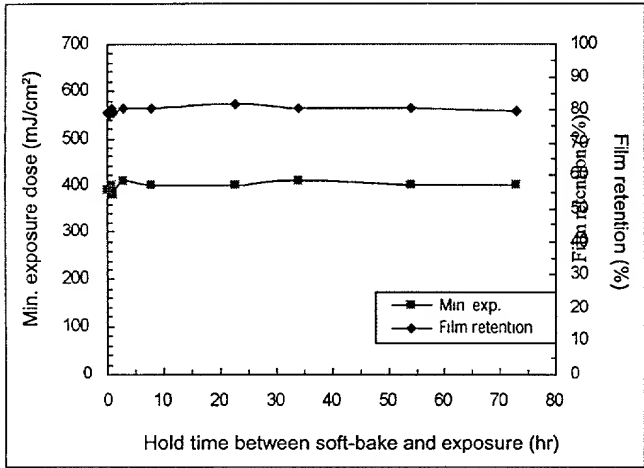


Figure 15. Minimum exposure dose and film retention vs. hold time between exposure and development with 8 μm-cured standard condition

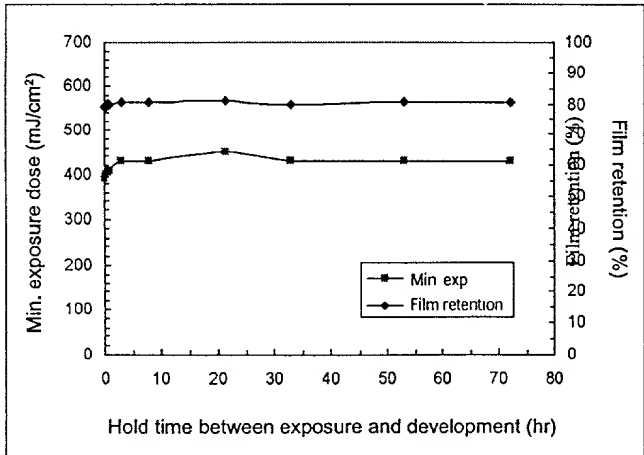


Figure 16. Critical dimension for 5 μm mask vs. hold time between soft-bake and exposure (5 μm cured)

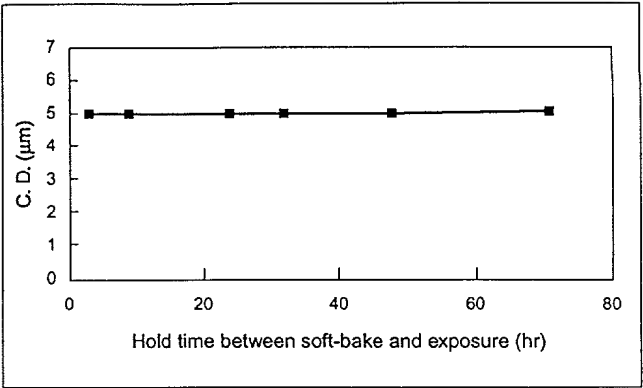
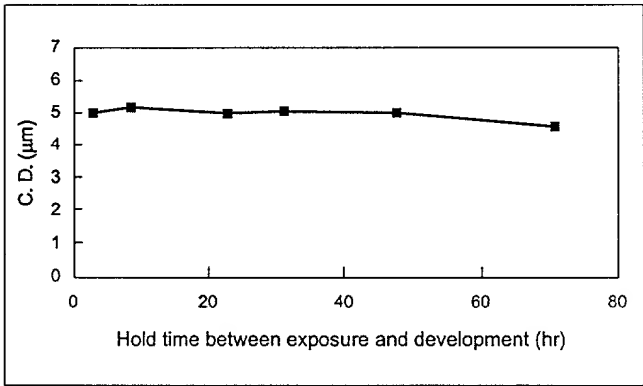


Figure 17. Critical dimension for 5 μm mask vs. hold time between exposure and development (5 μm cured)



5.9 Cure Process

The objectives of a proper cure schedule are to:

1) remove residual solvents, 2) complete the imidization process, 3) complete the adhesion process. Because all three of these actions can occur simultaneously at a given temperature, the cure schedule is a very important process step which can impact cured film quality and associated mechanical properties (see Table 7, Figures 18a–18f). The following variables need to be considered in curing polyimide films:

- Curing tool
- Atmosphere
- Loading temperature
- Ramp rate
- Soaks (holding temperatures)
- Final Cure temperature
- Ramp down

Curing is typically done as a batch process using programmable ovens or furnaces. (Single-wafer curing tools that utilize a series of hot plates have also been developed for in-line processing. This technique has been frequently used with non-photodefinable polyimides.)

Curing should be performed under a nitrogen atmosphere (oxygen conc. <100 ppm). Some programmable ovens are designed to cure under a vacuum. A partial vacuum may be used with a nitrogen atmosphere.

Loading temperatures, ramp rate, soaks (intermediate holding temperatures), final cure temperature and cool down rate can be optimized for optimum throughput and cured film properties. A basic cure schedule is given below for a typical "single-mask" stress buffer application.

Basic Cure Schedule for HD-8000

- Load into oven or furnace at <150 °C
- Ramp from loading temperature to 350 °C over a 60 minute period
- Hold at 350°C for 30 minutes
- Substrates can be unloaded immediately or allowed to cool down.

Furnaces can be routinely cleaned with a 700 °C cycle for 1 hour under air atmosphere.

5.10 Rework

Before curing, HD-8000 can be stripped with commercial cleaners commonly recommended for polyimide removal. Oxygen plasma etching can be used to remove both uncured and cured polyimide. Typical rework conditions are detailed in Table 6.

Table 6. Rework conditions

		Reagent	Condition	Remarks
After soft-bake and after development	strip	S-106	23°C/3 min	dip
	rinse	D.I. water	23°C/2 min	dip/spin dry
After cure	strip	S-106	105°C/3 min	dip
	rinse	D.I. water	23°C/2 min	dip/spin dry
After cure (Option)	strip	O ₂ plasma	300W	Yamato RFG-500A/PC-101A
	strip	2.5% HF	105°C/1 min	dip
	rinse	D.I. water	23°C/2 min	dip/spin dry

6. Cured Film Properties

6.1 General Properties

Cured films of the HD-8000 series exhibit a relatively high Tg, a moderate CTE and good elongation, as detailed in Table 7.

Table 7. Cured Film Properties

	Units	HD-8000
Tg	°C	300
CTE	ppm/°C	47
Tensile strength	MPa	122
Elastic modulus	GPa	2.5
Elongation	%	11
Weight loss temp.	°C	
1%		403
3%		421
5%		433
Adhesion	hr	>500
Dielectric constant at 1 kHz		3.4
Dissipation factor		0.0097

6.2 Cured Film Properties as a Function of Cure

The cured film properties can vary with final cure temperature. Some of these variances are detailed in Table 8 and plotted out in Figures 18a–18f.

Figure 18. Dependence of cured film properties on cure temperature

Figure 18a.

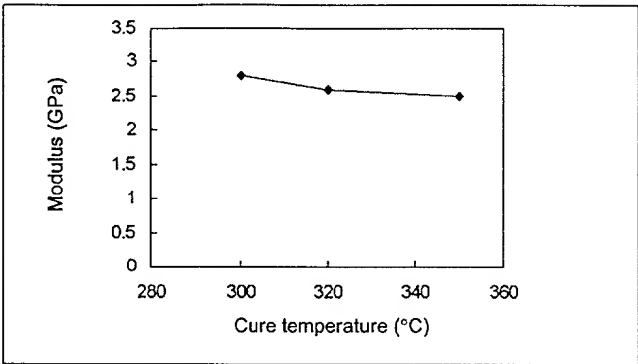


Figure 18b.

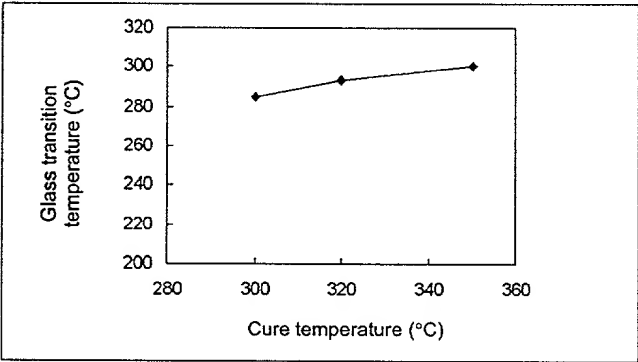


Table 8. Dependence of cured film properties on cure temperature

No.	Cure temp (°C)	Tensile strength (MPa)	Elastic modulus (GPa)	Elongation (%)	5% Wt. Loss (°C)	Tg (°C)	CTE (ppm/°C)
1	300	139	2.80	11.5	424	286	53
2	320	129	2.70	11.5	430	293	49
3	350	122	2.50	11.0	433	300	47

Figure 18c.

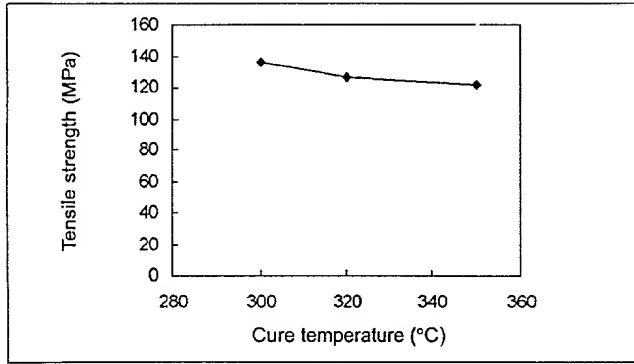


Figure 18d.

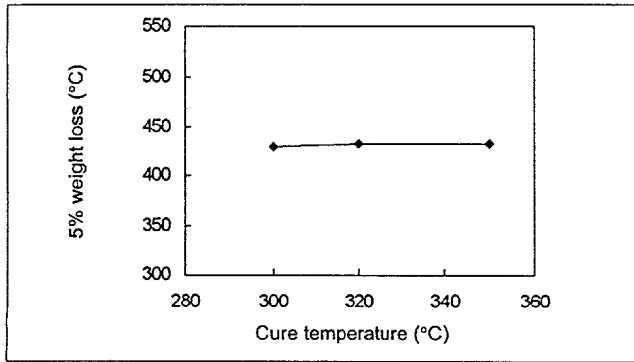


Figure 18e.

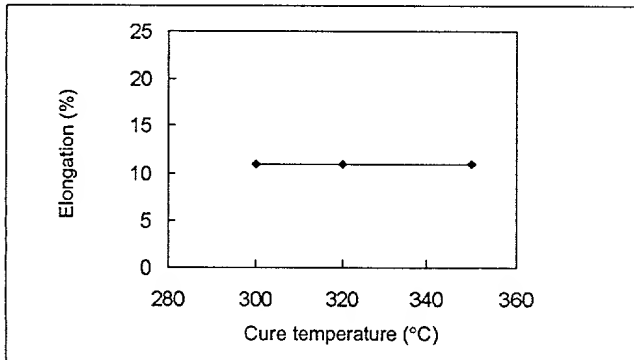
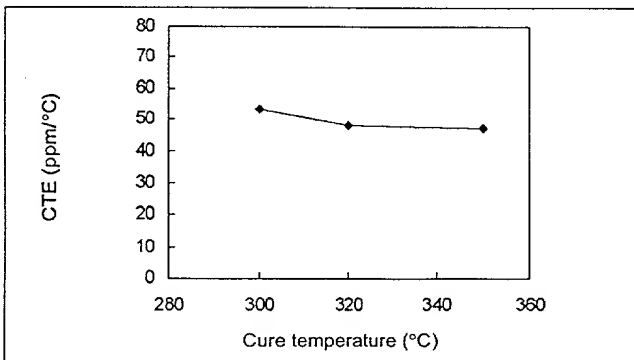


Figure 18f.



6.3 Optical Properties

The optical transmittance and optical density as a function of film thickness are plotted in Figures 19 and 20.

Figure 19. Optical transmittance spectrum of 5.7 μm cured film

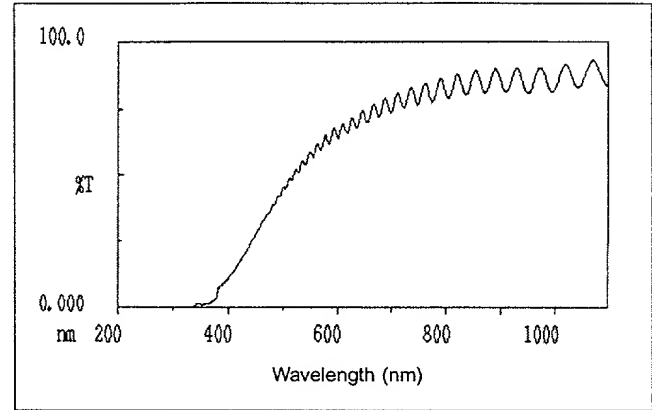
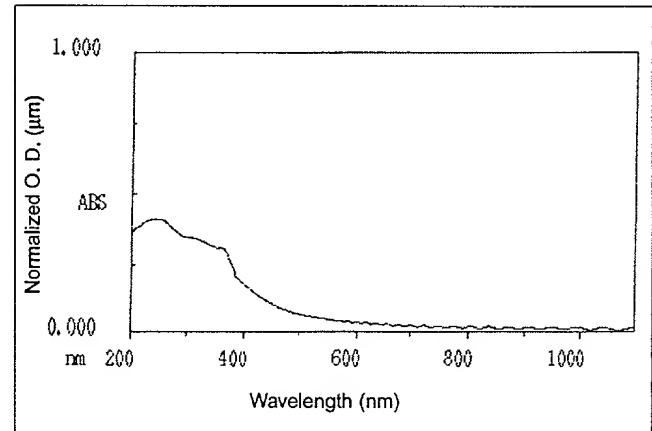


Figure 20. Cured film optical density normalized by thickness



6.4 Residual Stress

Residual or the internal stress in cured films was measured using a wafer bending technique. The measured stress is compared to a self priming wet etch polyimide, PIX-3400, in Table 9.

Table 9. Internal Stress (Wafer Bending)

		R_1 (m)	R_2 (m)	t (μ m)	σ (MPa)
HD-8000	1	-129.3	213.1	5.01	29.1
	2	-1668	84.05	5.01	29.3
	Ave.	—	—	—	29.2
PIX-3400 (ref.)	1	-3278	88.00	4.58	28.8
	2	-134	229.0	4.91	28.3
	Ave.	—	—	—	28.55

σ : Internal stress (MPa)

$$\sigma = E h^2 / (1 - \nu) 6 R t$$

R_1 : Radius of bare Si wafer (original bend)

R_2 : Radius of Si wafer after PI cure (bend by PI)

$$R = R_1 R_2 / (R_1 - R_2)$$

t : PI thickness (μ m)

h : Wafer thickness (625 μ m)

$E/(1 - \nu)$: Elastic modulus of Si wafer (1.805×10^5 MPa)

7. Dry Etch Resistance

Both soft-baked and cured films exhibit excellent resistance to dry etch processing chemicals. This versatility makes HD-8000 well suited for most single-mask wafer overcoat processes.

Silicon nitride and cured films of HD-8000 were measured after dry etch processing for film thickness, depth and pattern size.

The impact of etching gas composition on film thickness reduction and etch rate is shown in Table 10 and Figures 21 and 22. A higher O_2 ratio resulted in a larger film thickness reduction and a higher etch rate. Soft-baked films of the HD-8000 series have also shown good RIE resistance.

Table 10. Dry etch tolerance (etch rate μ m/min)

Gas composition CF_4/O_2	SiN	HD-8000
60/40	0.20	0.17
75/25	0.30	0.07
90/10	0.080	0.036

Figure 21. Dry etch rate of SiN and polyimide as a function of gas composition

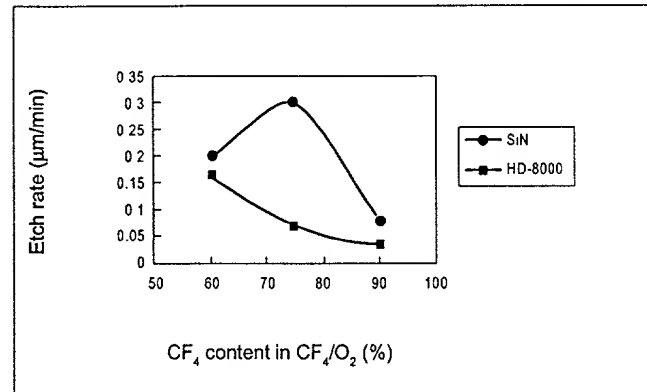
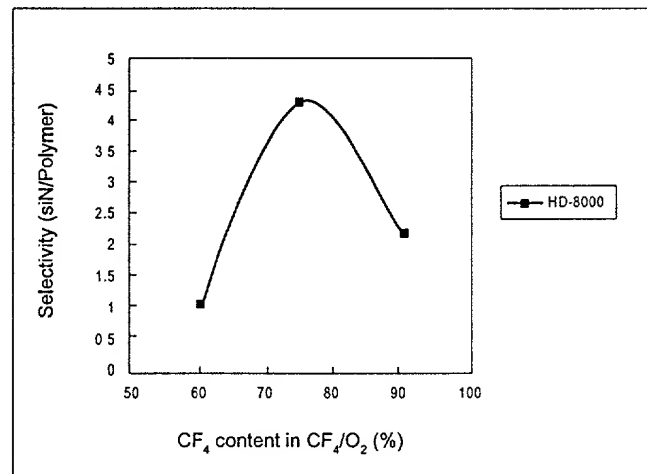


Figure 22. Selectivity of dry etch rate to SiN as a function of gas composition



8. Package Reliability

For packaging reliability, cured films were tested for adhesion to two types of molding compound types as a function of final cure temperature. PIX-3400 is an established self-priming, wet-etch polyimide stress buffer product and is included for reference purposes. Test results are shown in Table 11 and indicate that HD-8000 exhibited improved performance, independent of final cure temperature when tested with CEL-9200 and CEL-4690SX-4RU molding compounds.

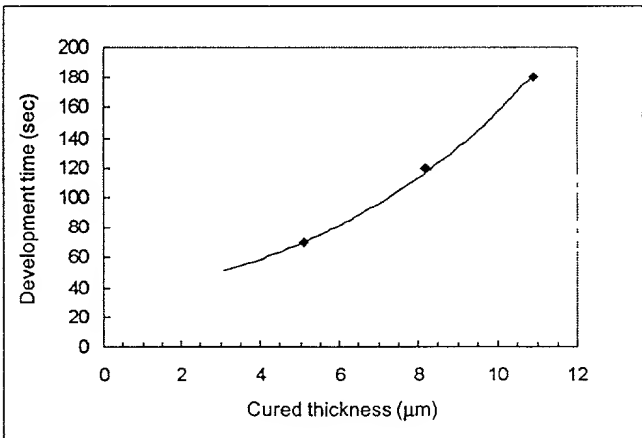
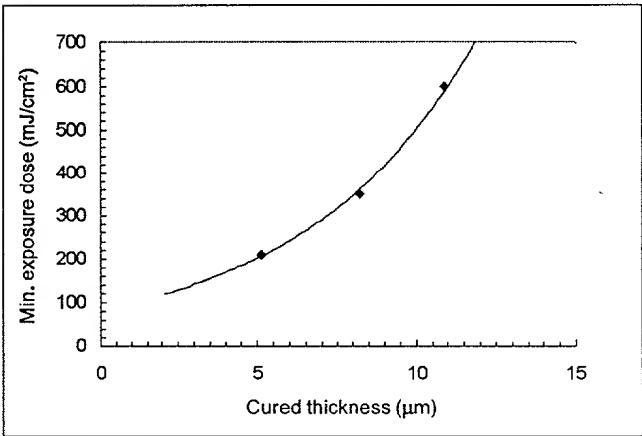
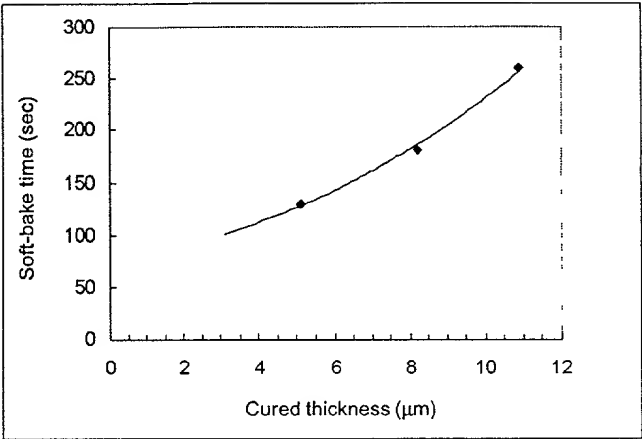
Table 11. Adhesion Strength to Molding Compounds

	CEL-9200	CEL-4690SX-4RU
HD-8000 300°C cure	4.9	7.4
HD-8000 325°C cure	4.5	6.7
HD-8000 350°C cure	4.6	6.4
PIX-3400 (ref.)	3.2	4.5

Stud pull method:
stud ϕ 3.65 mm
unit kgf/10.2 mm²
after PCT 85°C / 85% RH / 168 hr
measure temp. 250°C
shear speed 100 μ m/sec
Molding compound
CEL-9200: biphenyl type
CEL-4690SX-4RU: cresol-novolac type

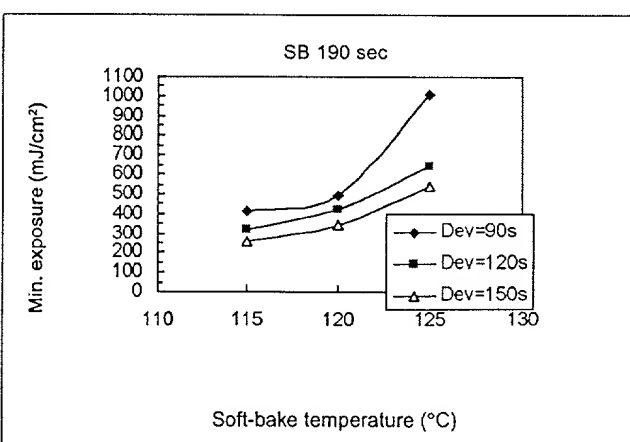
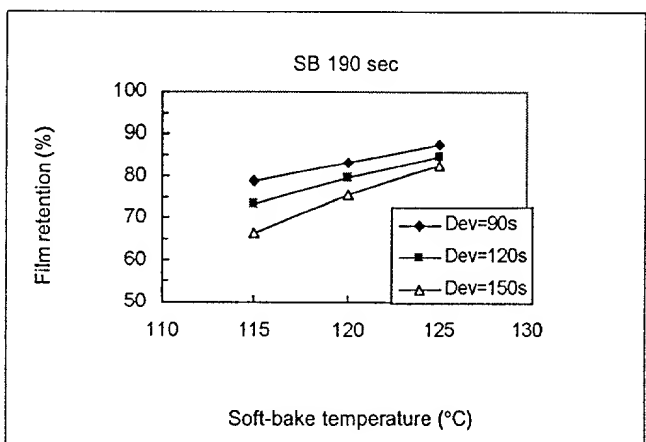
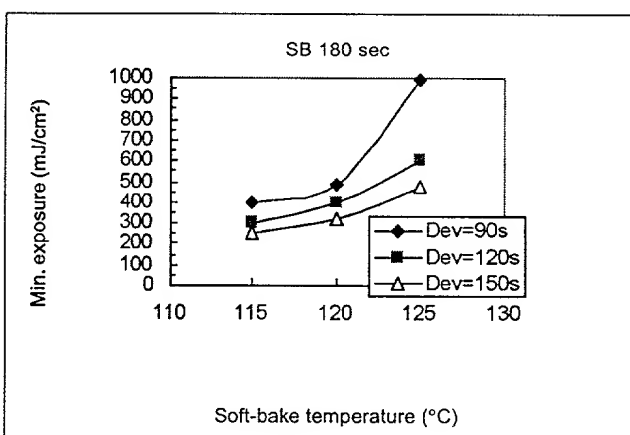
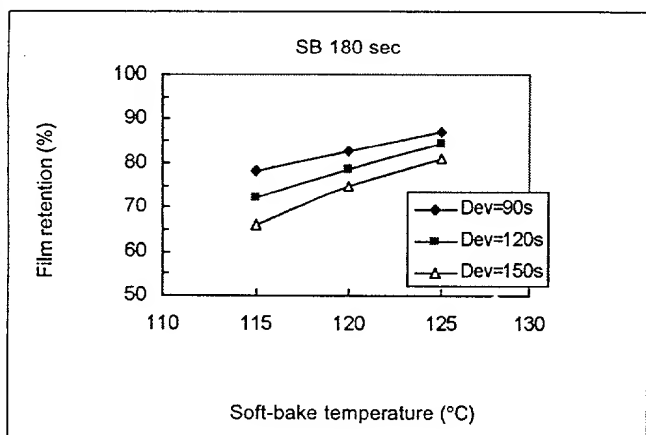
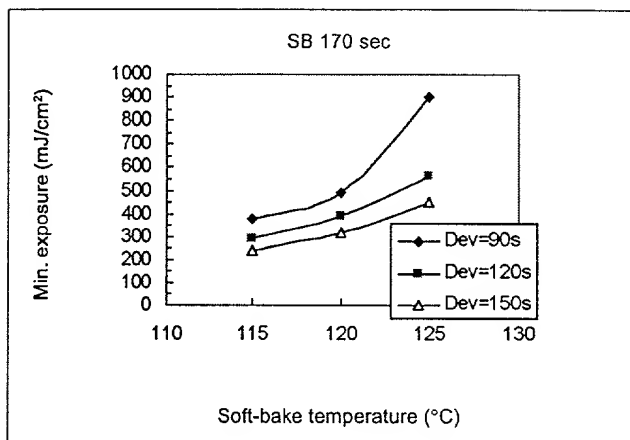
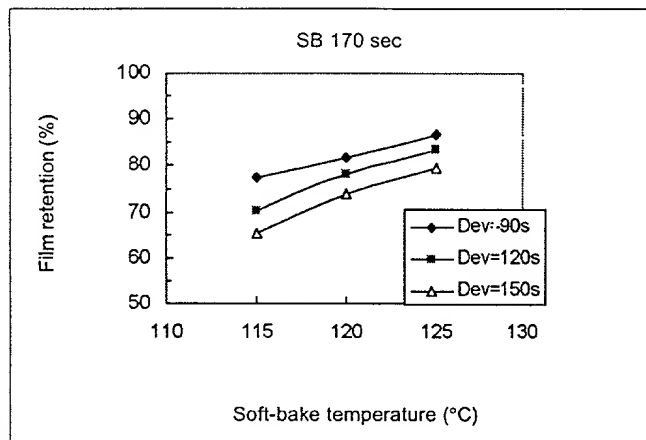
9. Appendices

9.1 Appendix A—Cured thickness and recommendable process conditions



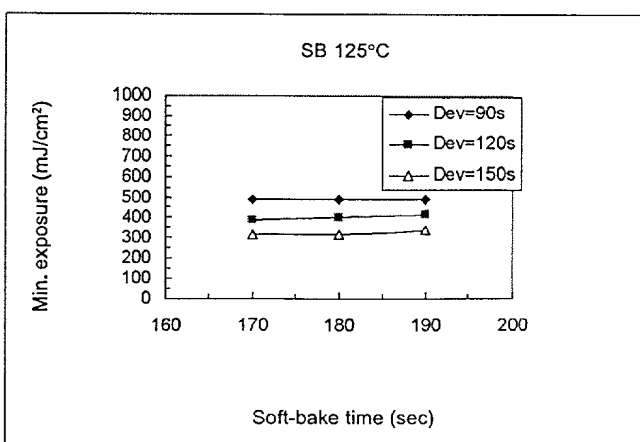
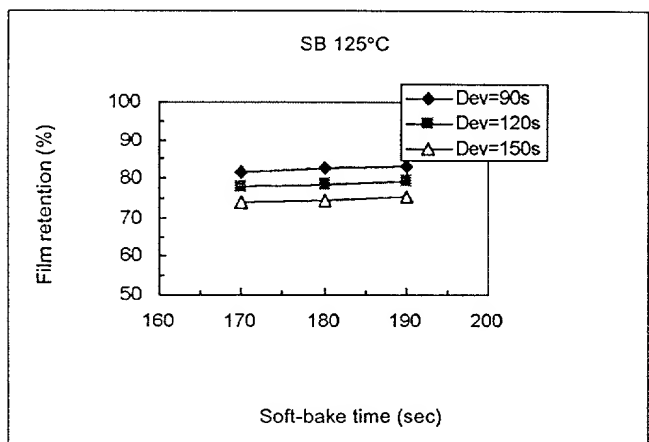
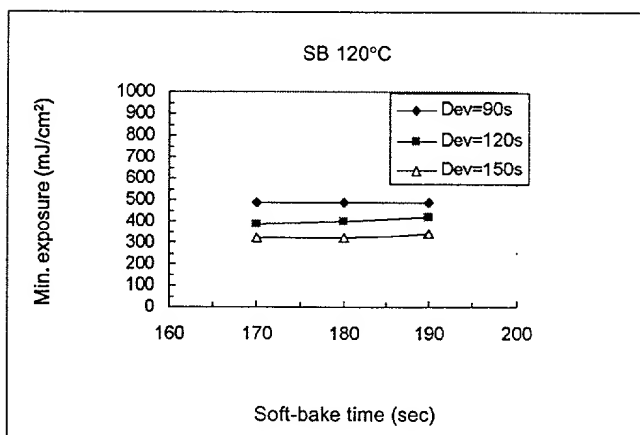
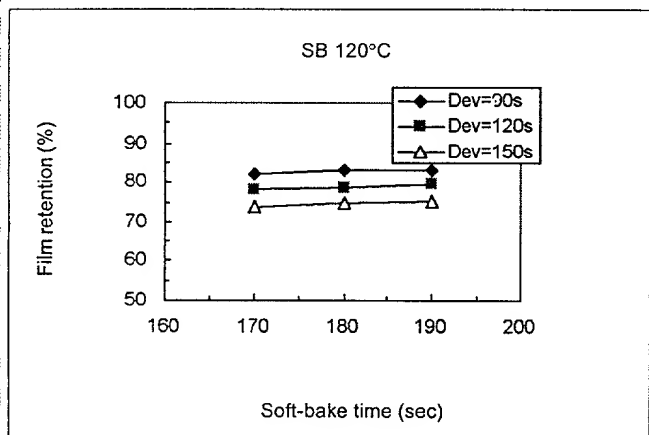
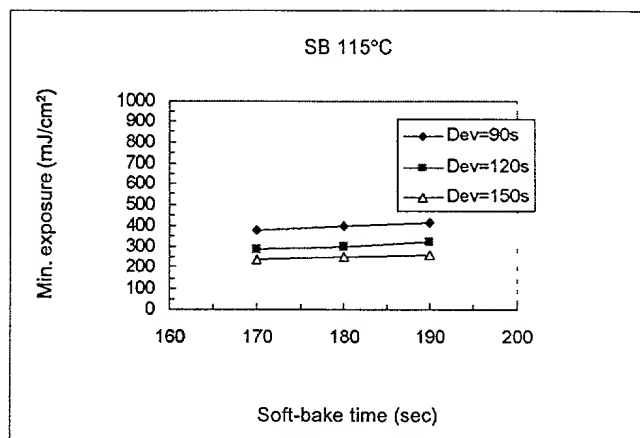
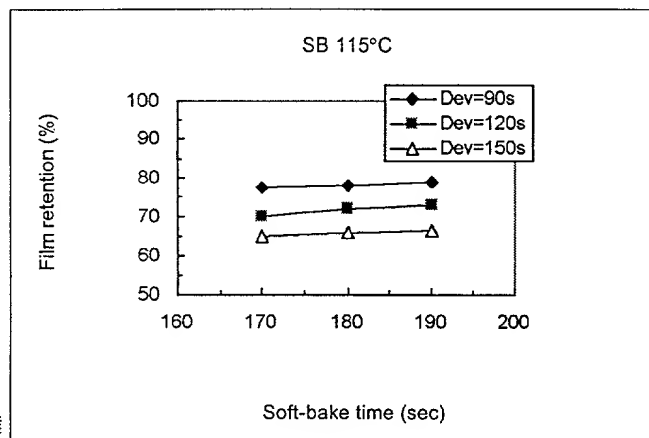
9.2 Appendix B—Soft-bake (SB) temperature margin (at 8 μm cured)

Film retention (left) and minimum exposure dose (right) as a function of soft-bake temperature at various development times. Soft-bake times are fixed at 170, 180, and 190 sec, respectively, from the upper



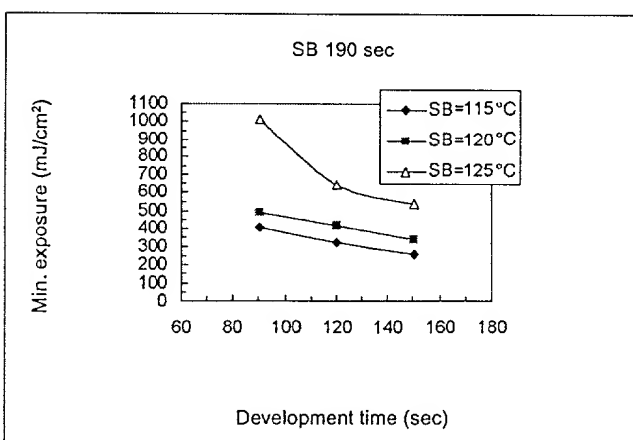
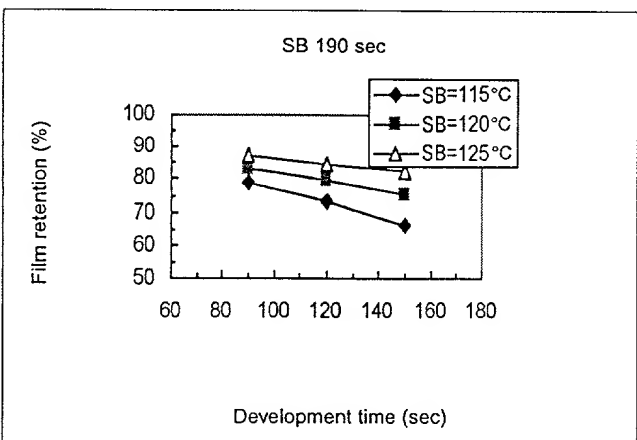
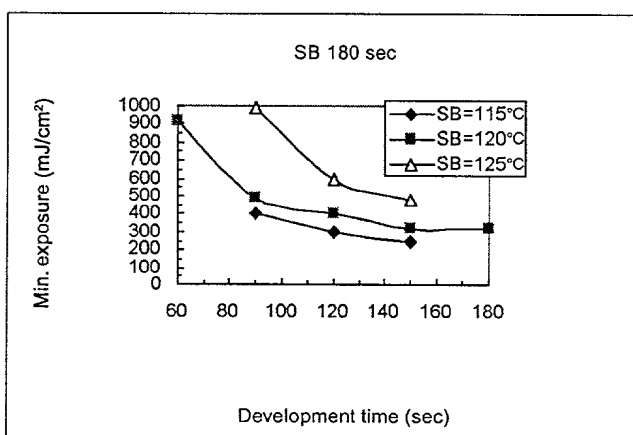
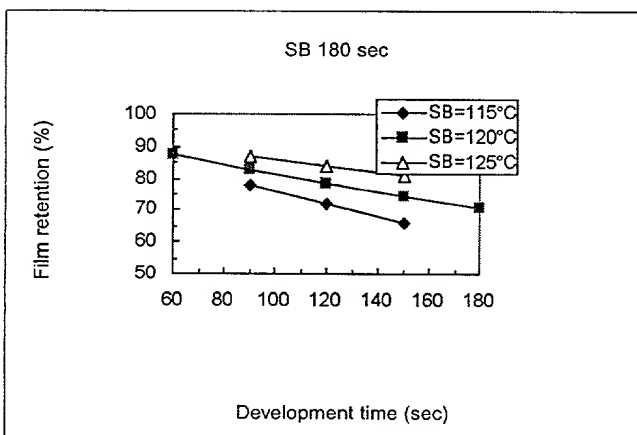
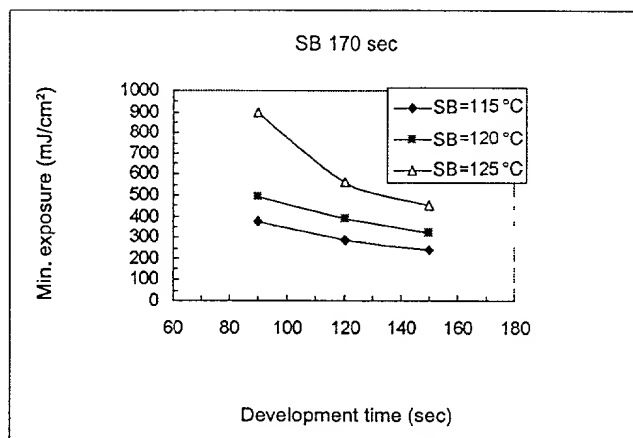
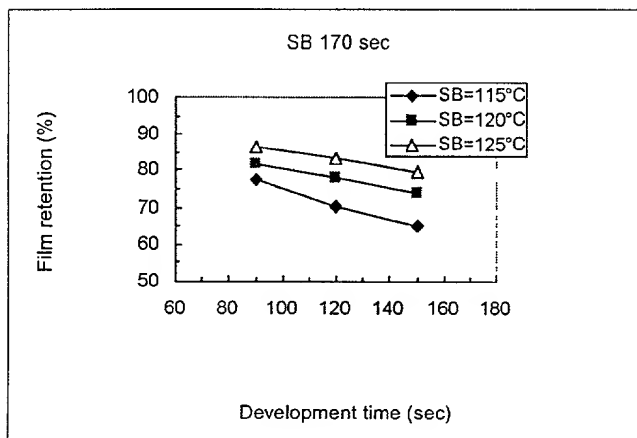
9.3 Appendix C—Soft-bake (SB) time margin (at 8 μm cured)

Film retention (left) and minimum exposure dose (right) as a function of soft-bake time at various development times. Soft-bake temperature is fixed at 115, 120, and 125°C, respectively, from the upper.



9.4 Appendix D—Development time margin (at 8 μm cured)

Film retention (left) and minimum exposure dose (right) as a function of development time at various soft-bake temperatures. Soft-bake times are fixed at 170, 180, and 190 sec, respectively, from the upper.



Summary

The HD-8000 series of photodefinable polyimides was developed through the collaborative efforts of the HD MicroSystems R&D laboratories in Hitachi City, Japan, and Wilmington, Delaware. The resulting product is a high-resolution, positive-tone photodefinable polyimide which can be imaged on I-line, G-line and broad band photo tools with tight CD control. As formulated, HD-8000 has excellent process latitude, with 72-hour hold-time stability and two week RT viscosity stability. Cured films of HD-8000 were measured to have good elongation, low stress and a high Tg. HD-8000's resistance to both wet chemicals and dry etch processing conditions is excellent, and make it well suited for various wafer overcoat processes.

Technical Service

HD MicroSystems has dedicated technical service facilities in Hitachi City, Japan and Wilmington, Delaware. Technical support personnel are available to work in-house on dedicated process tools, or on location throughout the world to assist in process development or to help resolve technical problems. For more information, contact your regional HD MicroSystems Technical Representative.

HD-8000 is a registered trademark of Hitachi Chemical Co., Ltd. © 1998 Hitachi Chemical Co., Ltd. All rights reserved.

© 1999 HD Microsystems, Inc. All rights reserved. Printed in the USA.

United States

HD Microsystems
PO Box 80010
Wilmington, DE 19880
800-346-5656 ext. 13 (Phone)
302-892-0597 (Fax)

HD Microsystems
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
800-346-5656 ext. 11 (Phone)
408-260-0885 (Fax)

Japan

HD Microsystems, Ltd.
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD Microsystems Europe GmbH
DuPont Strasse 1
61352 Bad Homburg
Germany
49-6172-87-1823 (Phone)
49-6172-87-1824 (Fax)

Internet

www.hdmicrosystems.com

HD Microsystems liability is expressly limited by HD Microsystems' Conditions of sale shown on Seller's price list or Buyer's copy of Seller's order acknowledgement form (if used) and Seller's invoice. All technical advice, recommendations and services are rendered by the Seller free of charge. While based on data believed to be reliable, they are intended for use by skilled persons at their own risk. Seller assumes no responsibility to Buyer for events resulting or damages incurred from their use. They are not to be taken as a license to operate under or intended to suggest infringement of any existing patent.

Caution: Do not use in medical applications involving permanent implantation in the human body.



HD Microsystems™
An Enterprise of Hitachi Chemical and DuPont Electronics